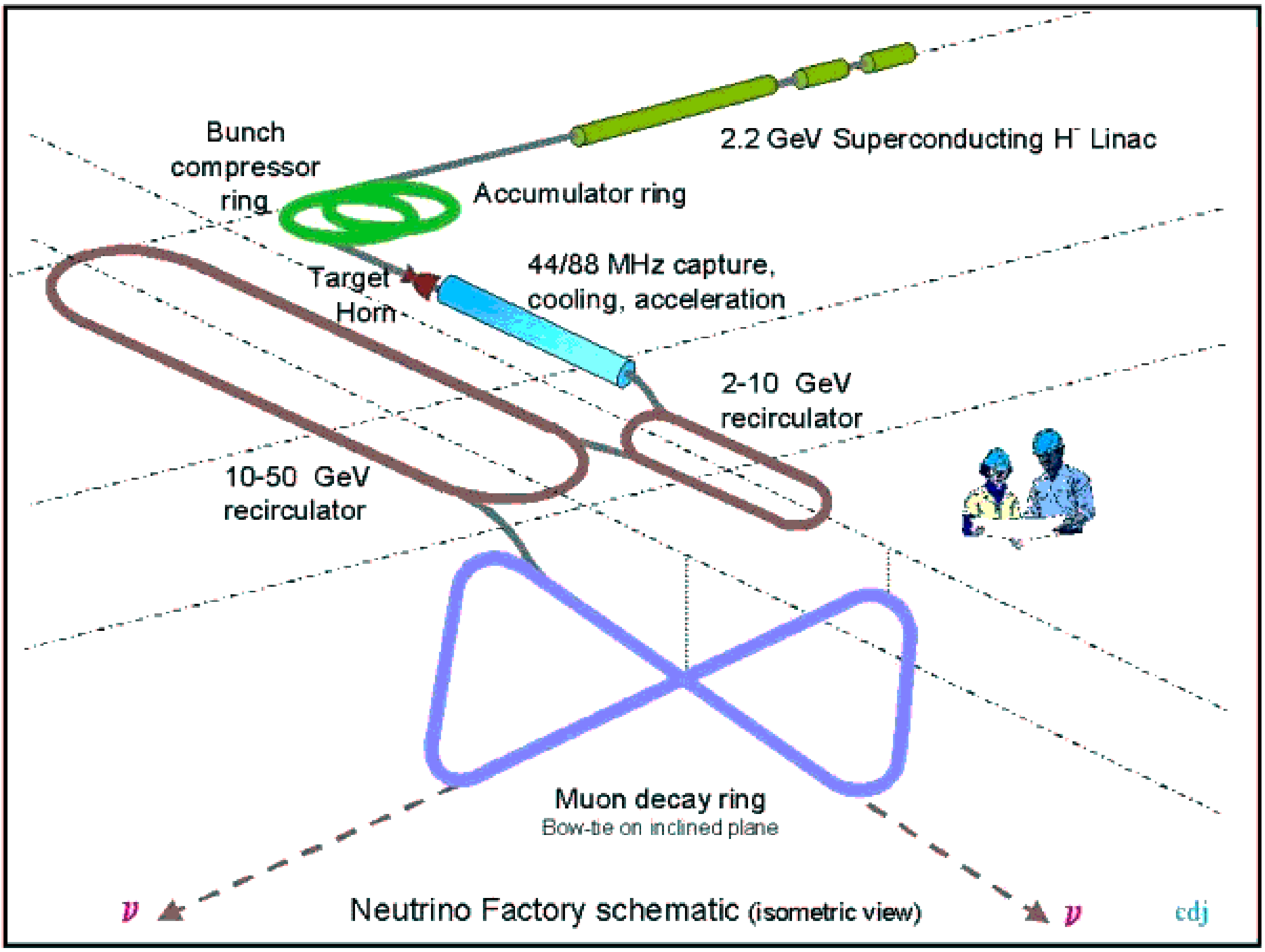
Talk 3

Oxford 11/01

R. B. Palmer

- CERN Study
- KEK Study
- FFAG's
- Bunched Phase Rotation
- Emittance Exchange
- Radioactive Ion ν's

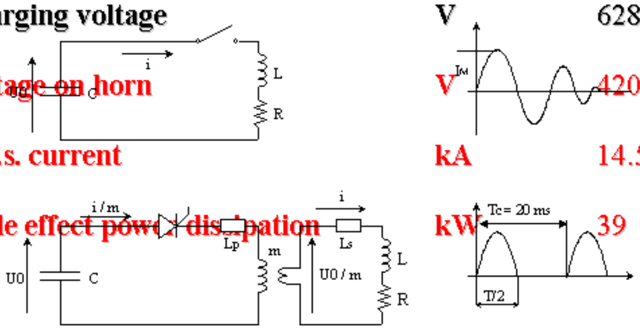
CERN Study

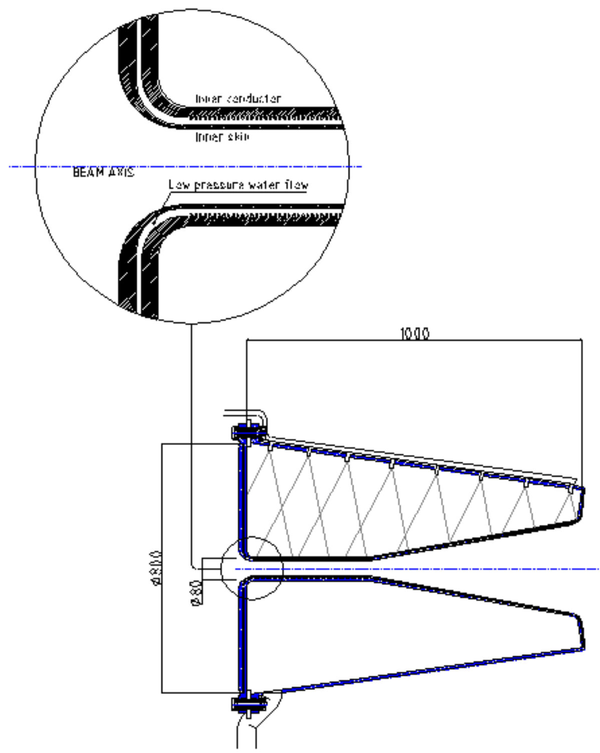


2.2 GeV protons
44 MHz spacing
50 Hz repetition

Pion Capture with horn

Type	mm	40-400
Waist radius	mm	40
Peak current in horn	kA	300
Total capacitance	µF	1453
Repetition rate	Hz	50
Pulse duration (half period)	µs	93
Charging voltage	V	6283
Voltage on horn	V	4200
r.m.s. current	kA	14.5
Joule effect power dissipation	kW	39





How long will it last?

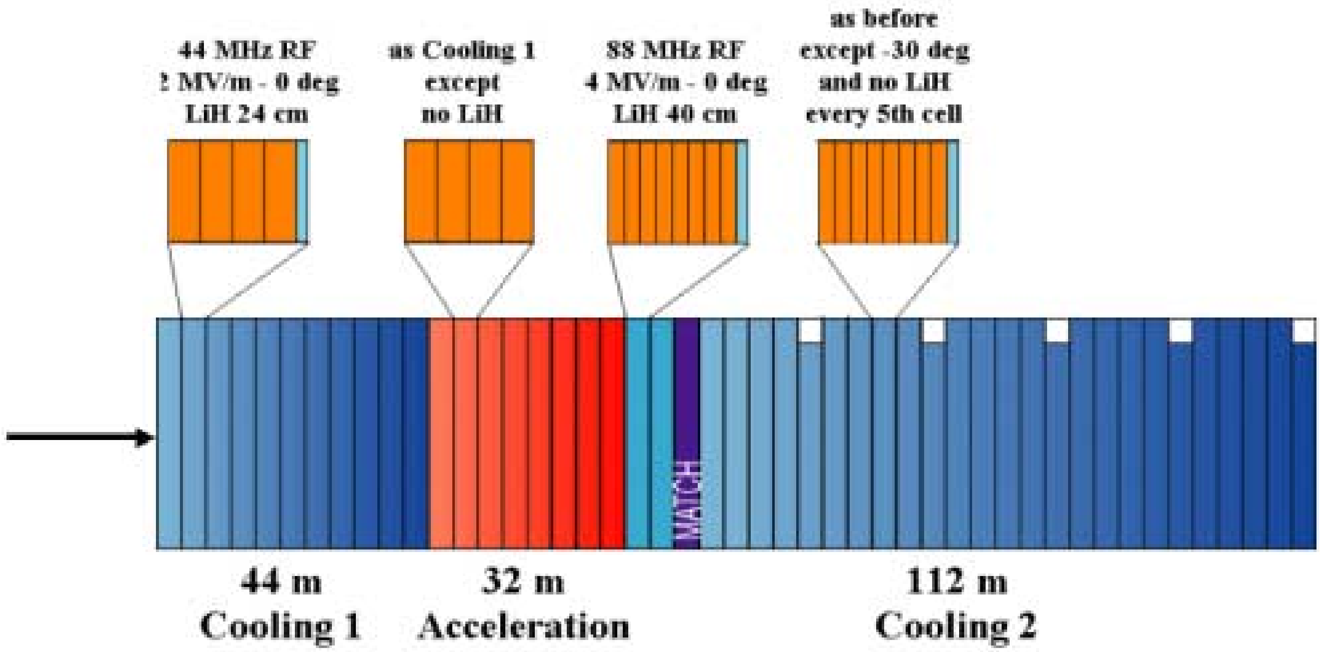
at 50 Hz c.f. fractions of a Hz

at 1 MW c.f. fractions of a MW

or 4 MW

Cooling with 44 & 88 MHz

	Decay	Rotation	Cooling 1	Accel. 1	Cooling 2	Accel. 2
Length (m)	30	30	46	32	112	~ 450
Diameter (cm)	60	60	60	60	30	20
B-field (T)	1.8	1.8	2.0	2.0	2.6	2.6
Frequency (MHz)		44	44	44	88	88 & 176
Cavities gradient (MV/m)		2	2	2	4	4 - 10
Kinetic energy (MeV)		200	200	280	300	2000



CERN vs. US Schemes

good: 2 GeV Linac is cheaper than 24 GeV ring
bad: space charge in p bunch worse by $(24/2)^2$

so: use many low intensity p bunches, 23 nsec apart

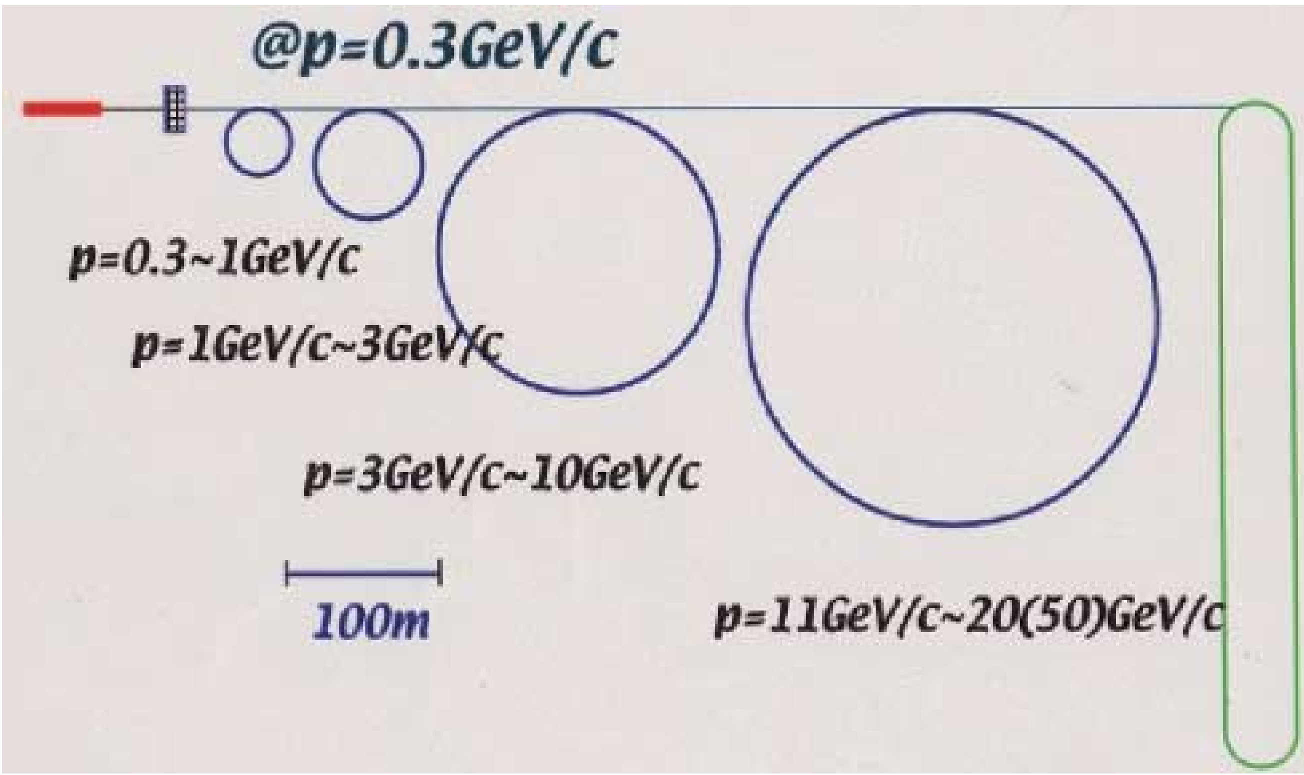
good: shock heating of target less
bad: phase rotation limitted to ≈ 3 ($4 \rightarrow 12$ nsec).
c.f. ≈ 8 ($12 \rightarrow 300/3$ nsec)
good: no need to rebunch
good: no need of induction linac
good: dp/p acceptance larger at low frequency
bad: lower accelerating gradient (4 MV/m at 88 MHz
vs. 16 MV/m at 200 MHz at same Killpatrick)
good: fraction of length with acceleration higher
bad: but length still 3 times greater for same cooling
bad: and thus more decay loss

A good feature of work at low frequency with no rebunching is that it will be needed for a collider. Although in that case the proton energy will need to be high to provide few large p bunches.

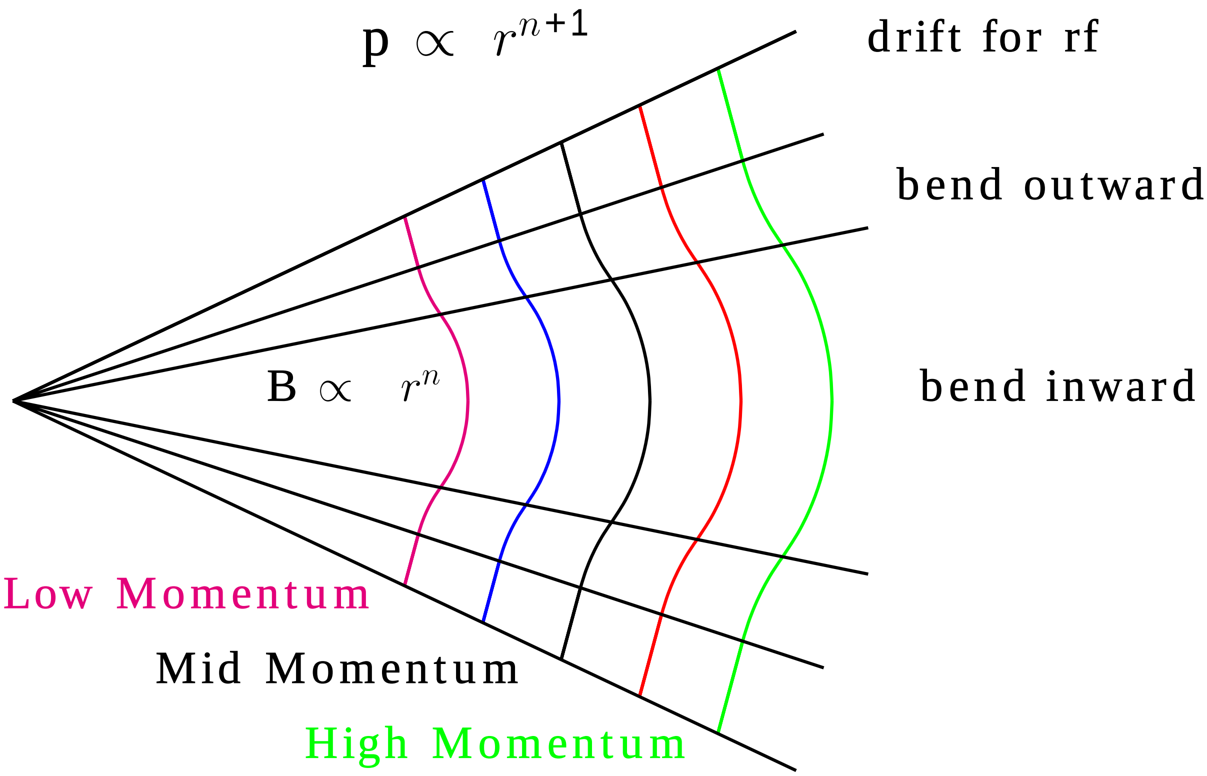
Performance estimates now similar, but simulation of CERN system used for this result used idealized fields, and may be optimistic

KEK Study

No induction phase rotation
No rebunching
No cooling
Use sequence of FFAG's



one piza slice of a Scaling FFAG



Δp limited only by aperture
typically 1:4
Non-isochonous
rf frequency very low or variable

POP FFAG at KEK

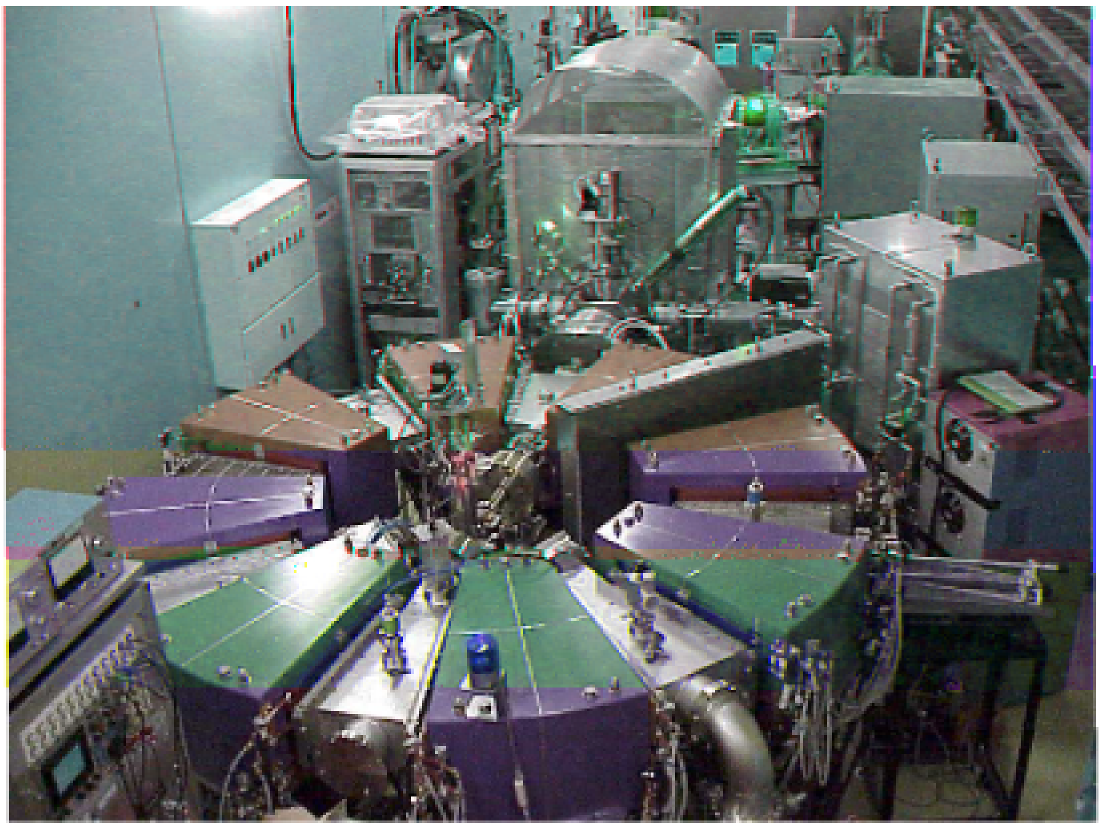
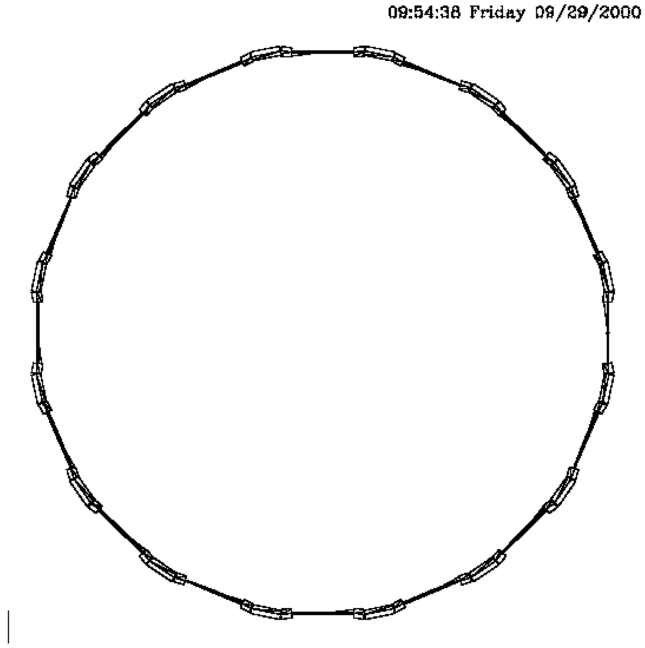
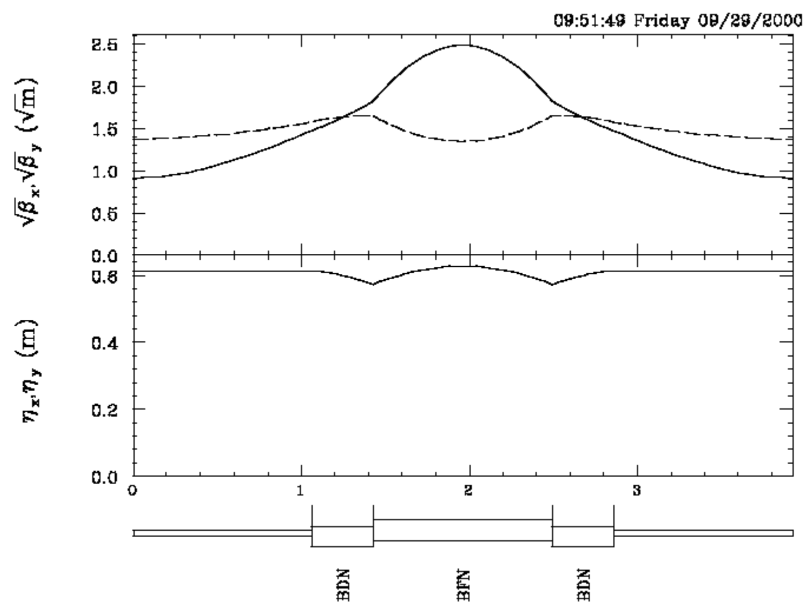


Figure C.2: Top-view of the POP FFAG

1-3 GeV Design



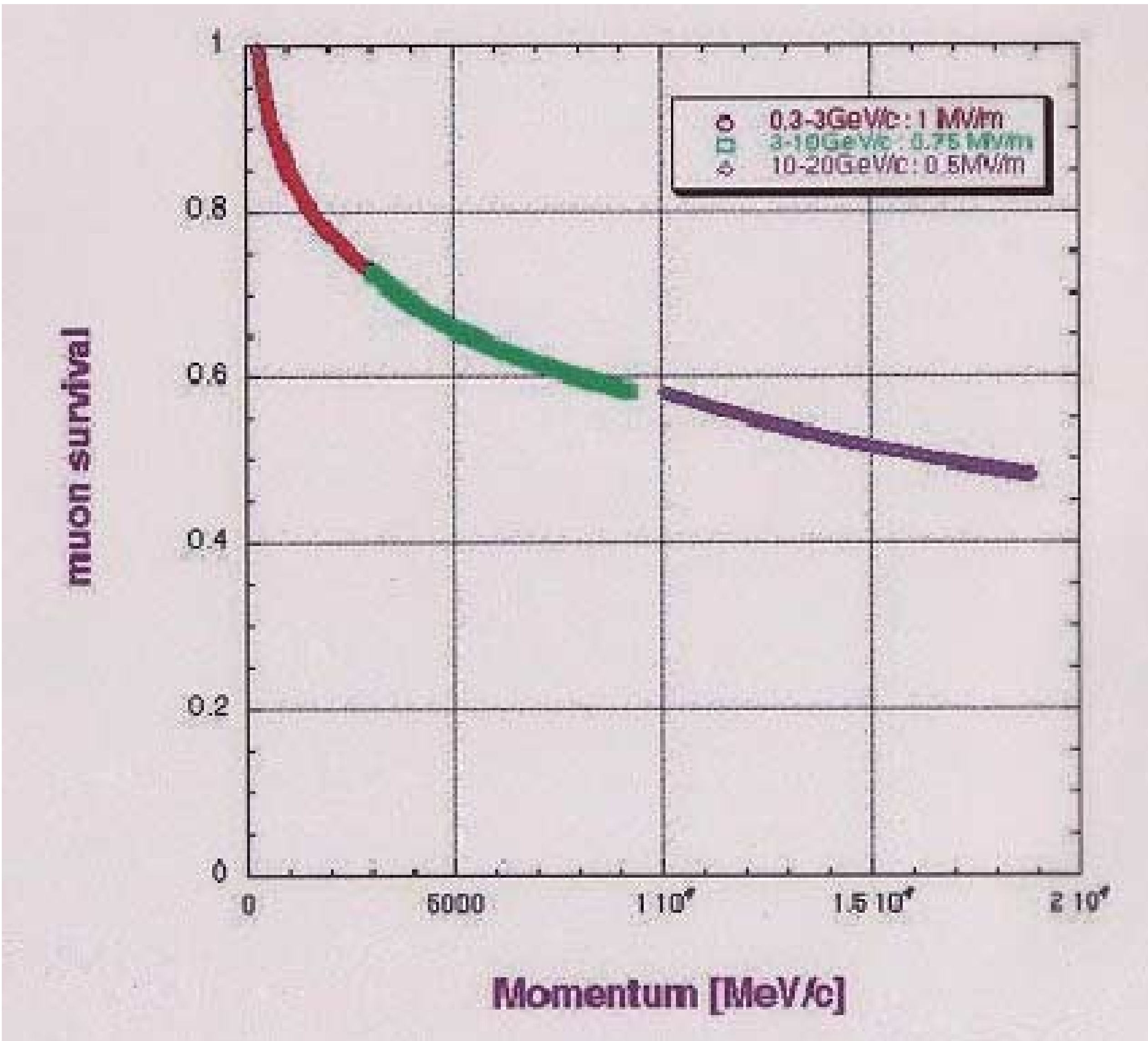


Loss by Decay

Frequency low

Gradients low

Larger Losses to decay



Loss to 0.46

Compare with Study 2

even: Transverse acceptances similar
good: Longitudinal acceptance larger
bad: Capture phase space less
good: no losses in rebunching
bad: more losses from decay

if Study 2 had no cooling: similar
but cooling gives study 2 factor of $\approx$ 3

	E_p GeV	μ/p cooled	acc loss	μ/p to ring	μ/p/GeV %
KEK	50	.3	.46	.14	.27
Study 2	24	.17	.8	.14	.58
Without cooling	24	.06	.8	.048	.2

Injection & extraction Problem

Cost less: more turns, less rf
Cost more: lower frequency
Cost less: single vs. multiple arcs
Cost more: larger circ (rev bends)
Cost more: larger apertures
???

Non-Scaling FFAG

Semi-conventional quadrupole and bend ring with very strong focussing

- Momentum acceptance $\approx$ 1:3
- Approximately Isochronous
- Can use high frequency SC rf
- More e cient and faster acceleration
- Limited number of turns

Same injection & extraction prob.

Cost less: more turns, less rf
Cost less: single vs. multiple arcs
Cost more: larger apertures
???

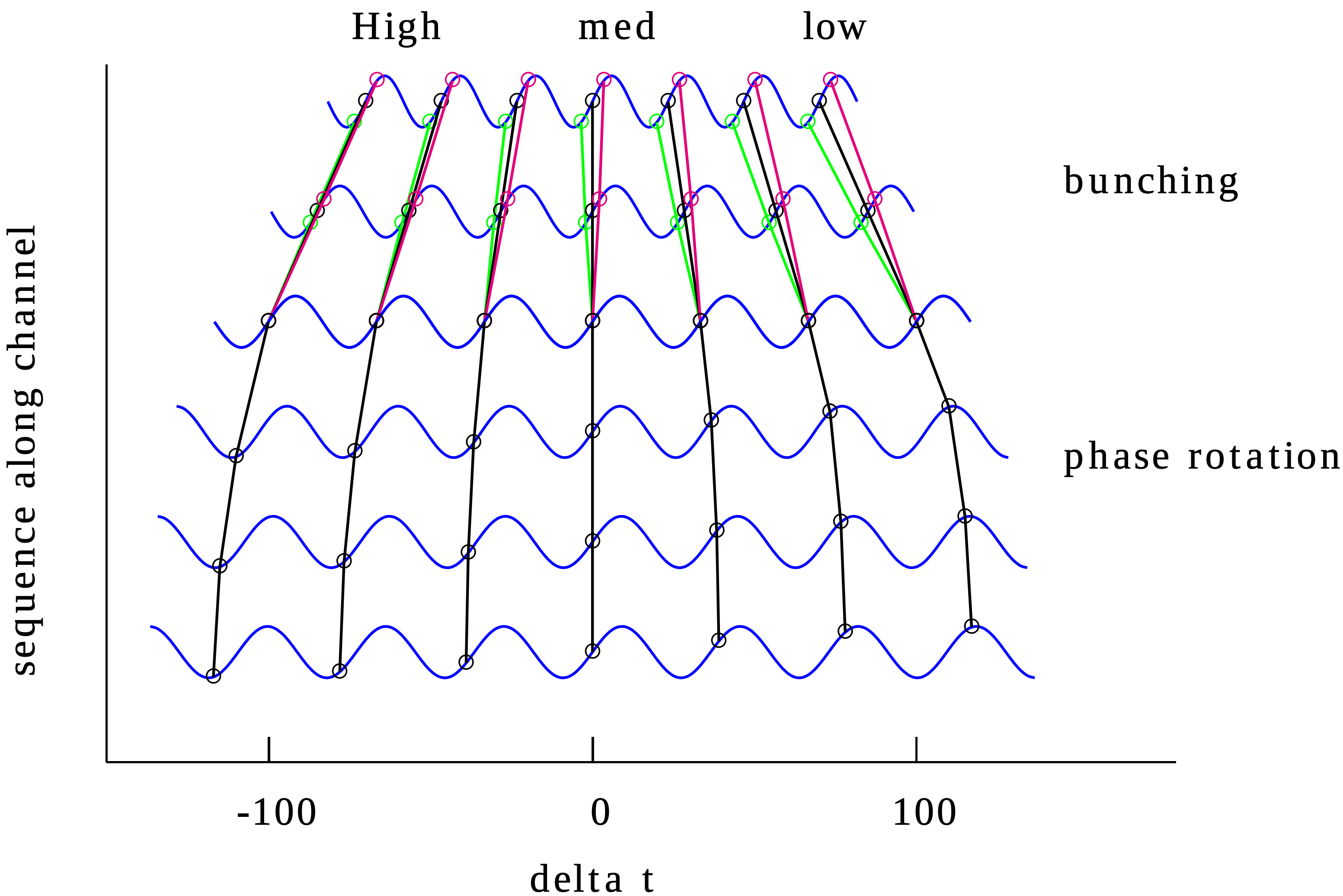
Bunched Phase Rotation

Drift
Bunch
Rotate with high freq. rf

vs. Conventional

Drift
Rotate with induction linac
Bunch

Bunched Phase Rotation



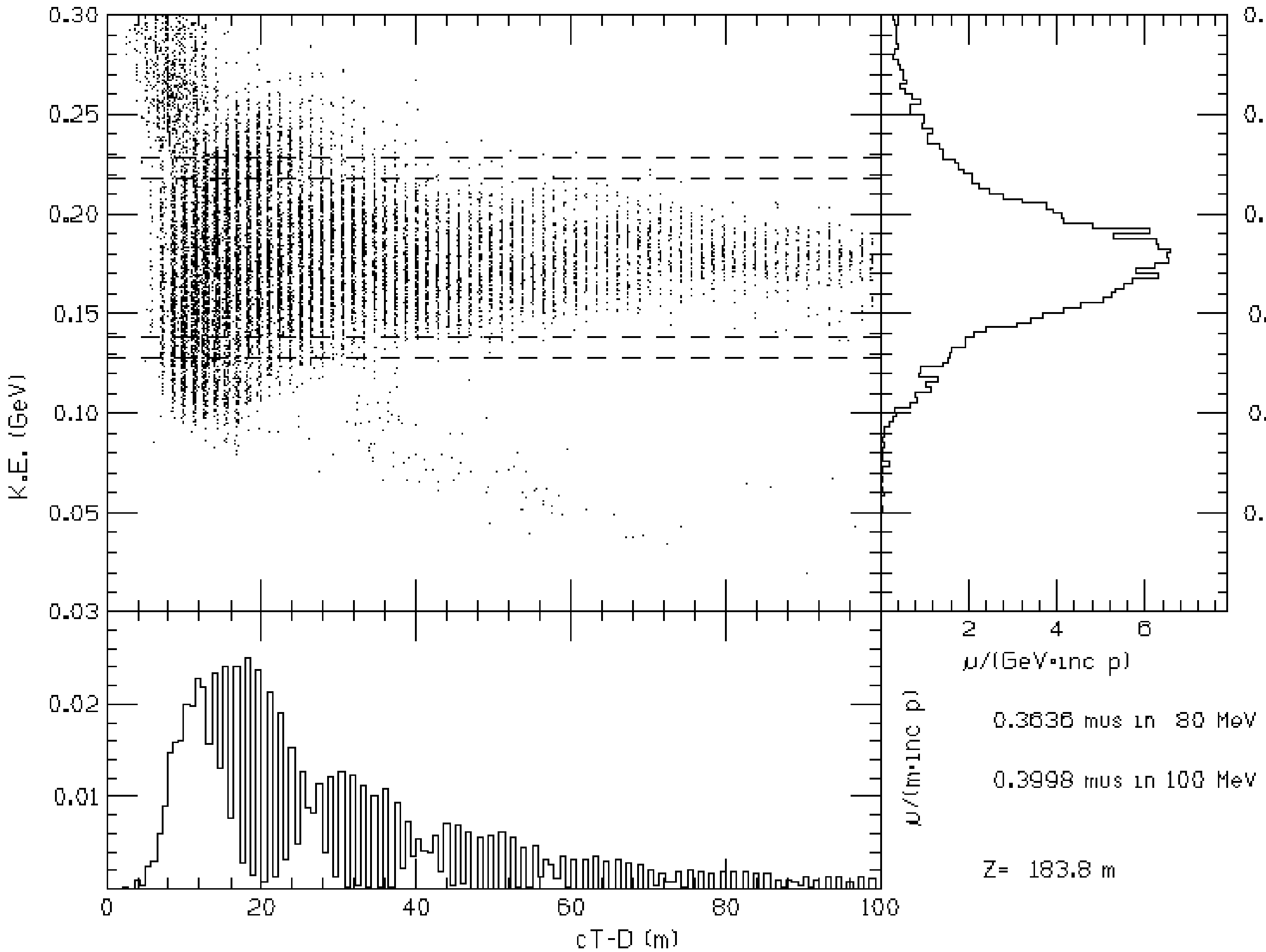
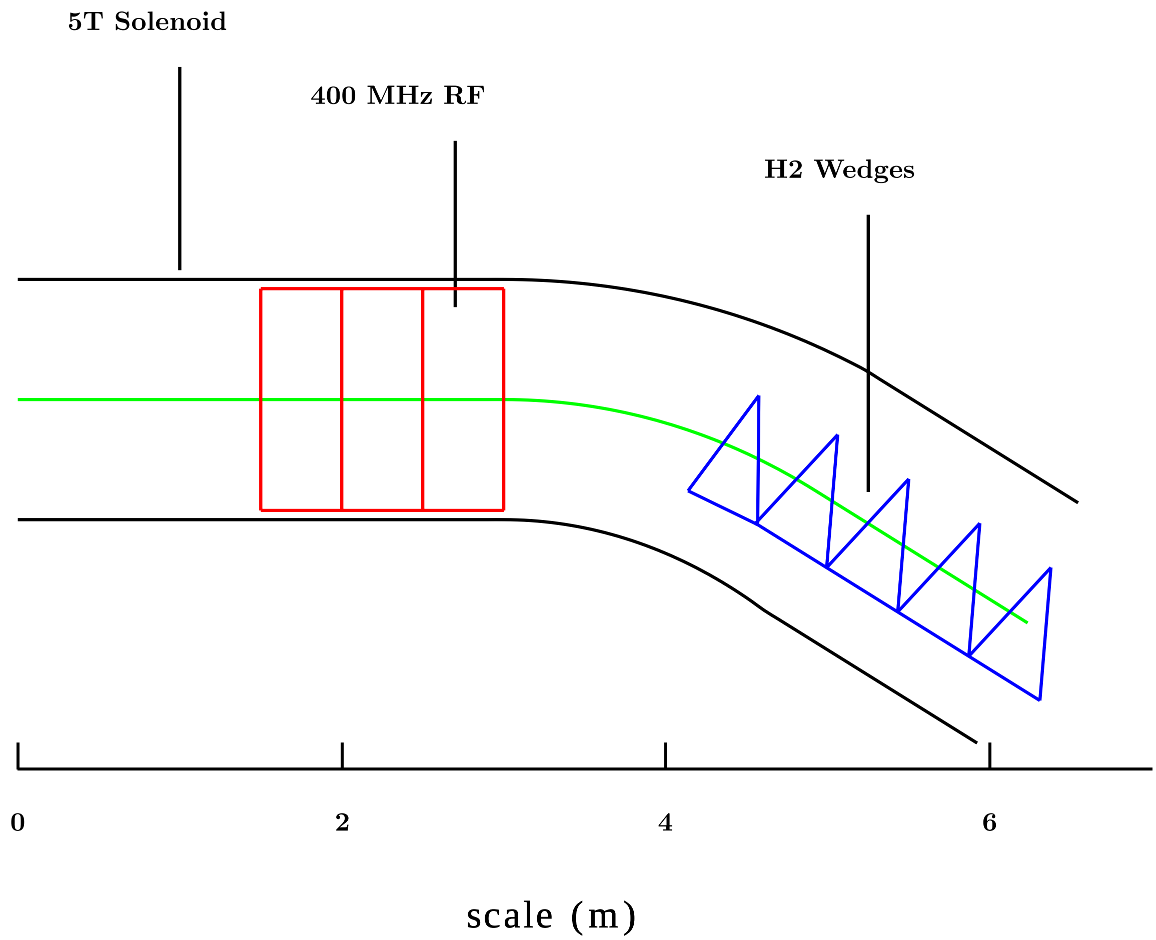


Figure 7: Muon distribution in (E, t)-space along with marginal distributions for 38 vernier (d=0.16) cavities followed by 23 (matched) fixed frequency cavities *generated with* ICOOL *program.* N_b=20 in buncher part. Plots and numbers quoted are based on 188 000 incident protons.

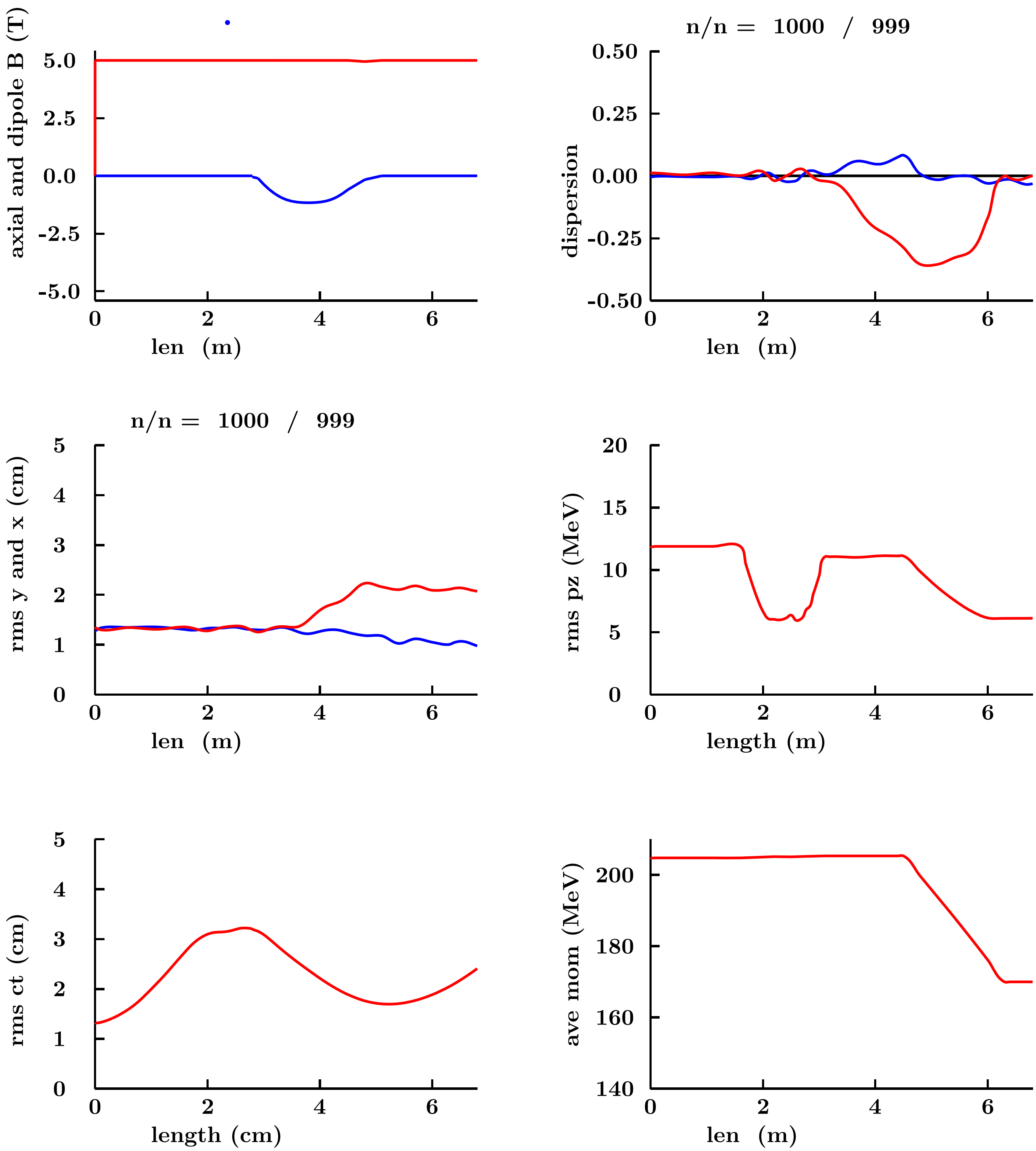
Distorting
Somewhat less e cient for one sign
But both signs rotated

Cost less: no induction
performance better: both signs

Bent Solenoid Emittance Exchange



Tracking in ICOOL



- Longitudinal emittance $\times\ 0.65$
- Transverse xy emittance $\times\ 1.36$
- 6D emittance $\times\ 0.88$
- expected from linear theory: $\times\ .68$
- 6D dilution:$\times\ 1.3$
- Transmission 100 %

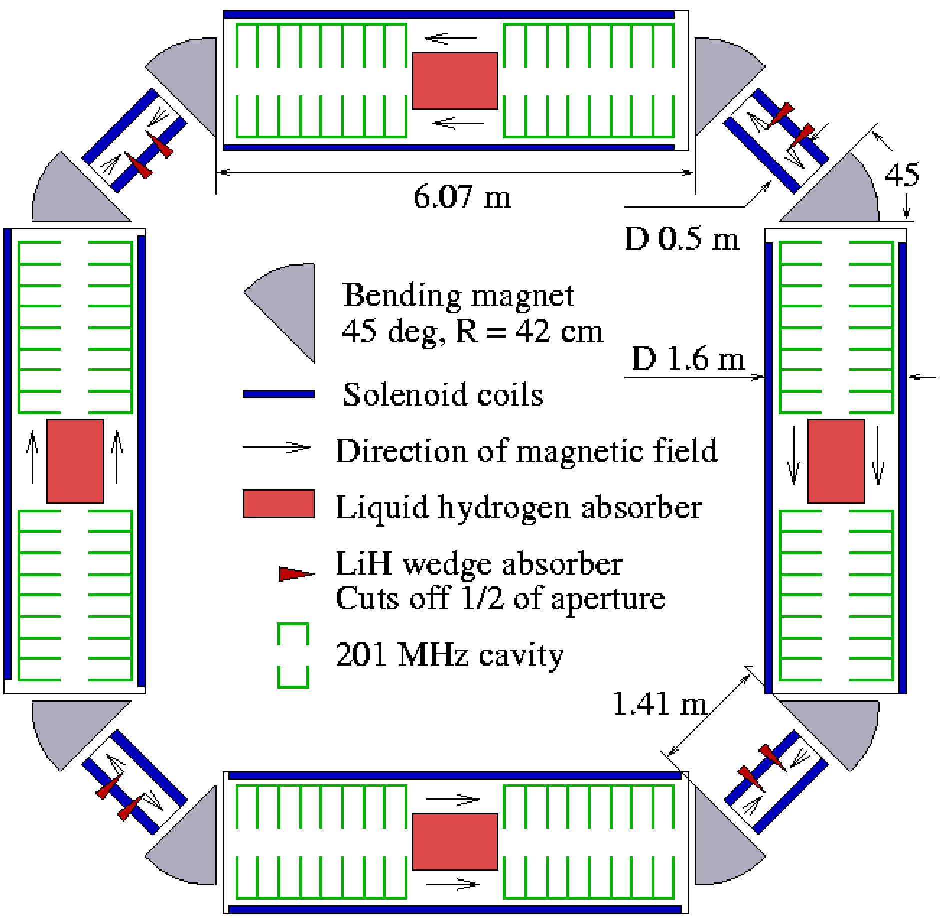
- 6D Emittance exchange is demonstrated
- all non linear e ects are included

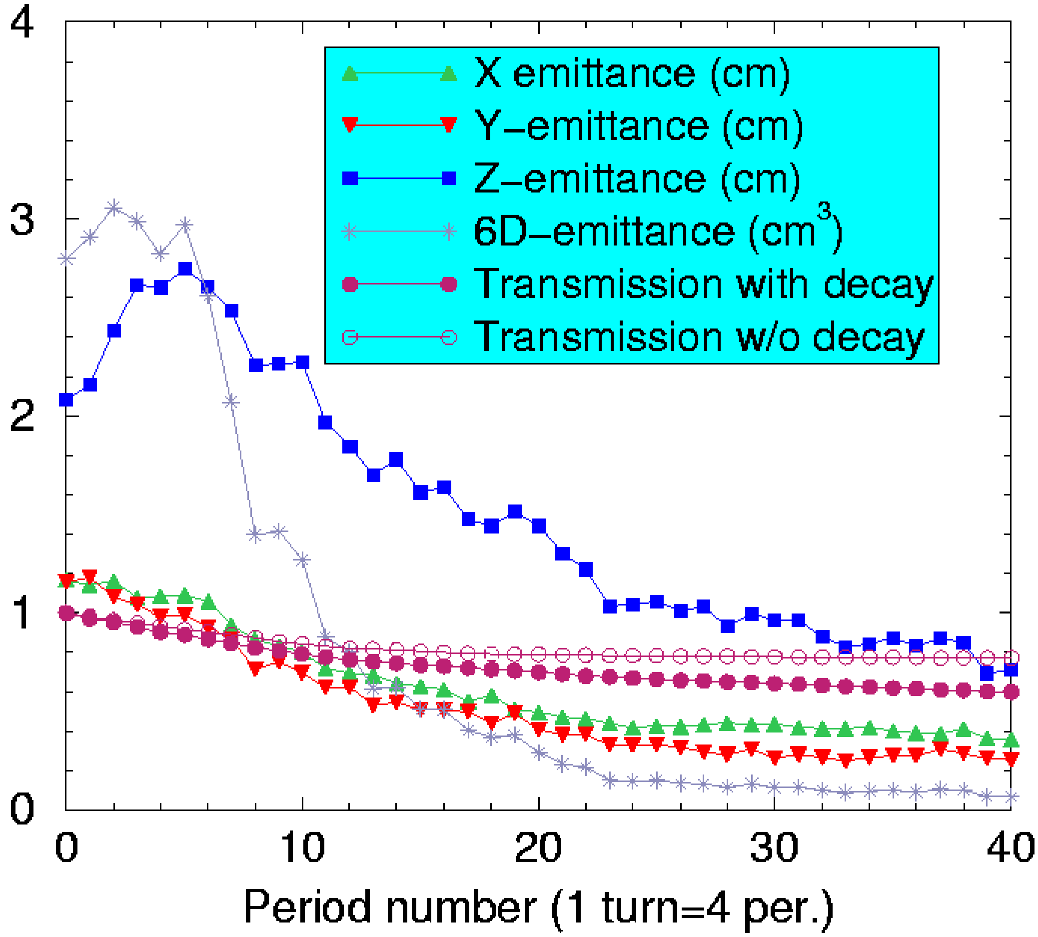
- exchange only with x, needs second bend
- Matching such exchange into a linear channel di cult
- Try combined cooling and exchange

Balbekov 6D Cooling Ring

Alternate transverse cooling with H2 with emittance exchange in Li wedge

Cools all 6 dimensions





Good cooling in all dimensions
More loss than desired

Calculated without Maxwellian fields
Design of bends proving hard
Injection and extraction hard
Uppward spiral an alternative

RFOFO Ring 6D Cooling

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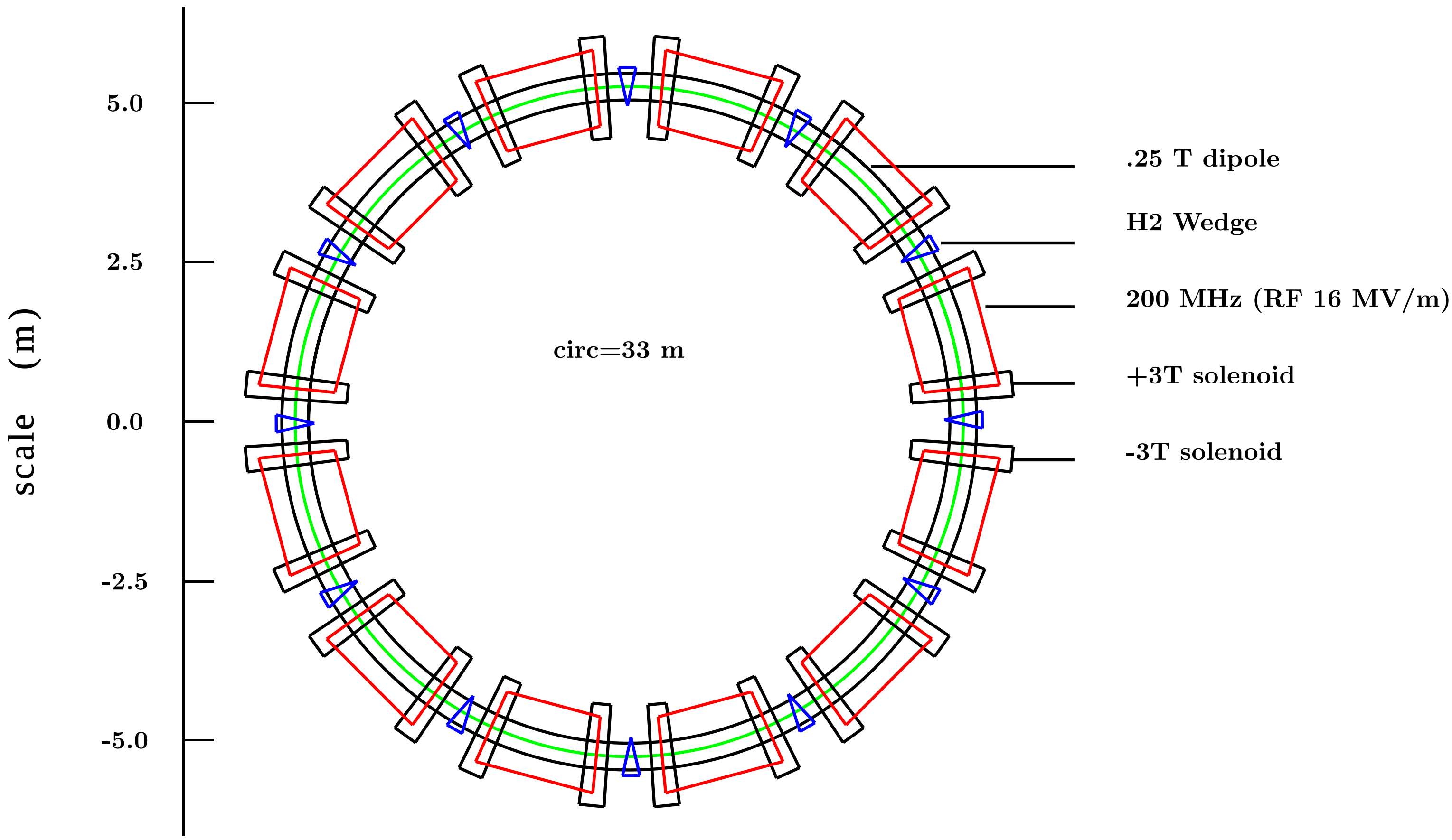
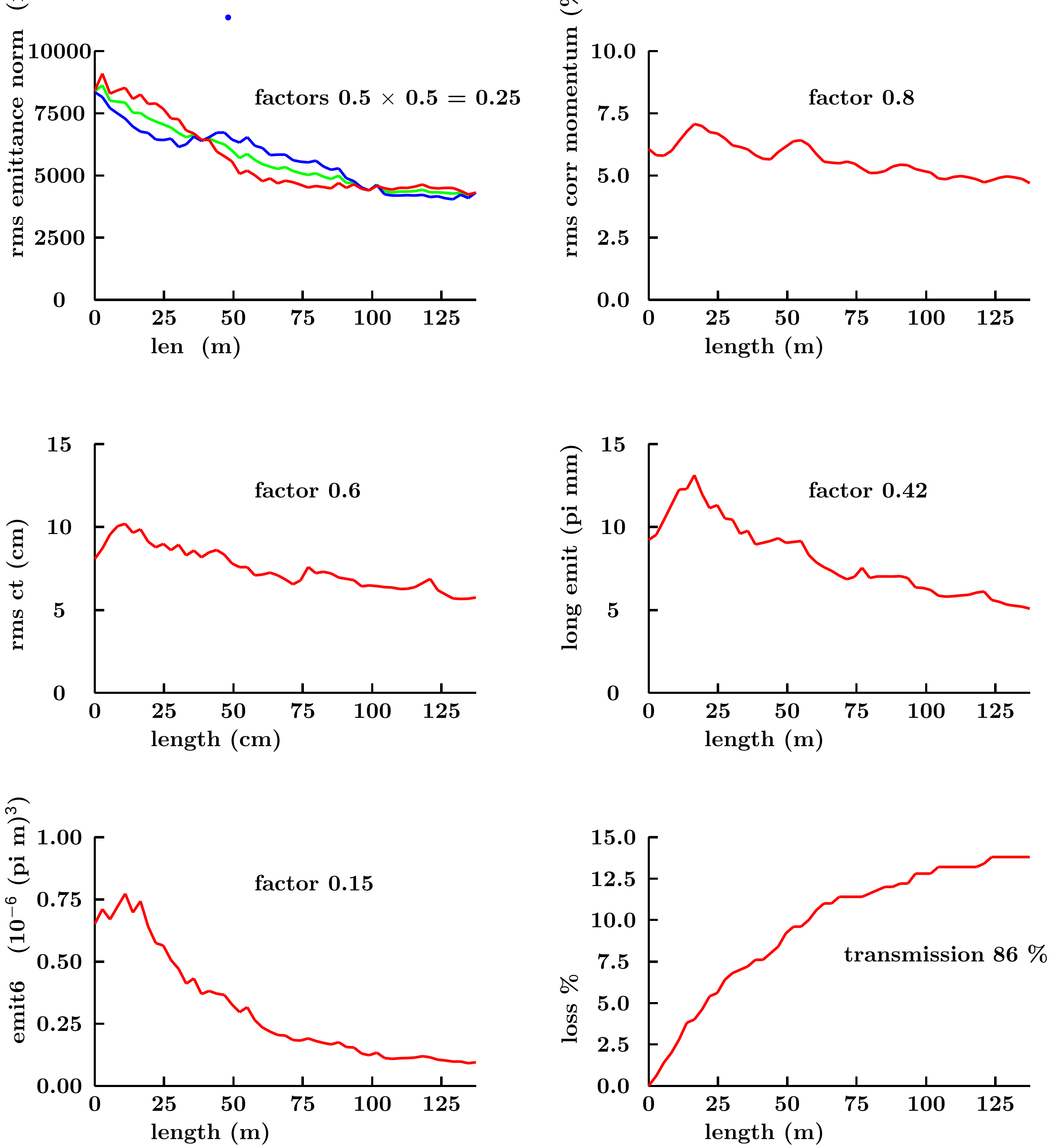
(Oct 01 LBL)



Tracking of Ring from Gaussian

With RF, wedge, scatter and straggle



- Longitudinal emittance $\times$ 0.42
- Transverse xy emittance $\times$ $(.5)^2 = 0.25$
- 6D emittance $\times$ 0.15
- Transmission 86 %
- Quality Factor ($\epsilon_{in}/\epsilon_{out} \times$ Trans $= 5.7$

Fully Maxwellian fields
But not too practical
Cooling in 6 D
Good transmissian
Injection & extraction hard
Upward spiral alternative

Radioactive Ion ν Prod.

$$X \longrightarrow Y + e + \nu$$

$E_\nu \approx 5$ MeV

Boost by γ of accelerated Ion
eg use 1 TeV ring $\gamma \approx 500$

$E_\nu \approx 2.5$ GeV

Decays in ring will quench SC magnets.
Need new specially shielded 1 TeV accelerator !

Internal conversion:

$$X + e \longrightarrow Y + \nu$$

No change in ion charge
Small change in ion momentum
slow departure from orbit
Use periodic collimators

???????????????????????????????

Conclusion

- Many Good Ideas
- Much work to find if workable
- More work to find costs

- Real hope of performance gains
- Real hope of cost reductions